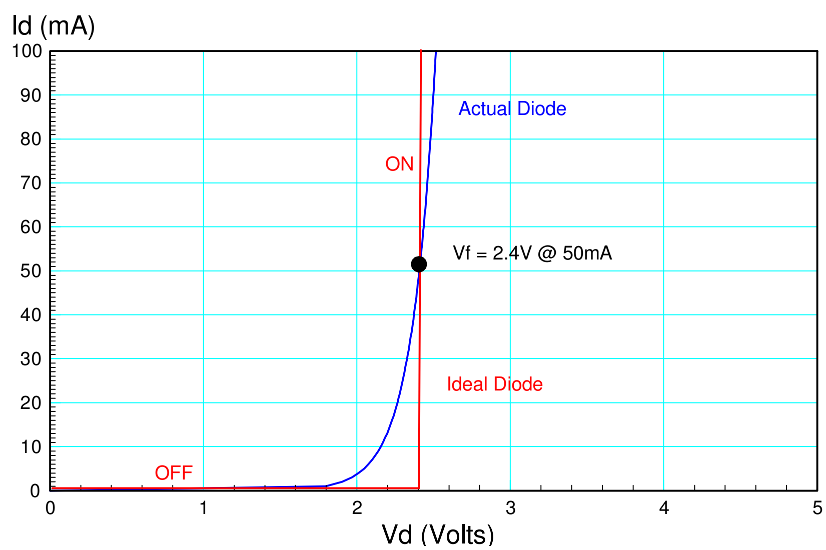
Binary Outputs: LEDs

1W Star LED, 10mm 0.5W White LED, and Piranha RGB LED

Light Emitting Diodes (LED's)

- Are diodes, allowing current to only flow in one direction,
- They convert current to light.(light is proportional to current flow),
- They are *very* fast, capable of over 1000 flashes per second, and
- They are a simple way to output binary data (light on / light off)

Like all diodes, the V/I characteristics are exponential in nature - similar to the figure below.



Typical VI characteristic for an LED (blue line) and an ideal diode approximation (red line)

This nonlinear relationship makes diode circuits difficult to analyze. To simplify analysis, an ideal diode model is used

- When the diode is on, the voltage across the diode is assumed to be constant
- If the voltage drops below a threshold (Vf), the diode is assumed to be off (current equals zero)

This is also how LED's are specified

- Vf: The voltage drop across the diode when on
- Typical mcd: The amount of light the LED outputs at a given current level
- Color: Kind of self evident
- Wavelength: A more accurate way of specifying the color of the LCD

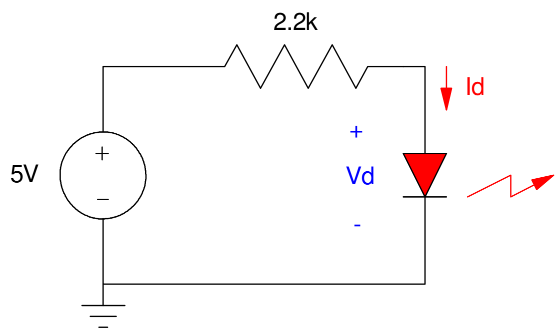
For example, the diodes in room 211 have the following parameters:

LED	Wavelength	Imax (mA)	mcd @ 20mA	Vf @ 20mA	Price (ea)
Piranha RGB	630 nm (r)	25 mA	10,000	1.8V	$0.56
	520 nm (g)	25 mA	10,000	3.0V	
	470 nm (b)	25 mA	10,000	3.0V	
0805 Red LED	625 nm	20mA	180	2.0V	$0.19
10mm Red	625 nm	120mA	20 LM	2.15V	$0.31
10mm Yellow	592nm	120mA	15 LM	2.15V	$0.50
3W White	n/a	750mA	200 LM	3.4V	$1.90
10W White	n/a	1000mA	650 LM	11.0V	$7.62

http://www.ebaystores.com/lighthouseleds

Example 1: The circuit boards used in ECE 376 use the 0805 LED listed above (or similar). Determine

- The current Id and
- The brightness in mcd



Solution: Assuming ideal diodes

$$V_d = 2.0V$$

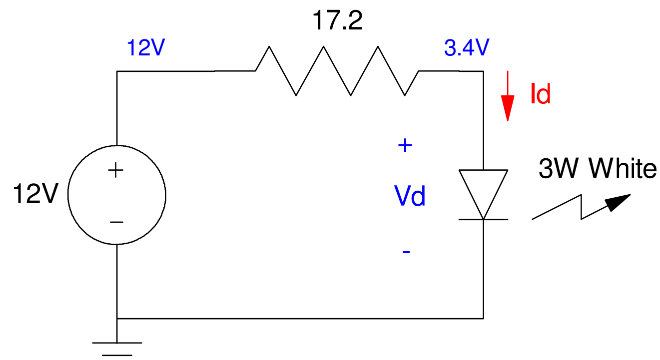
$$I_d = \left(\frac{5V - 2.0V}{2.2k}\right) = 1.3636\,mA$$

$$light = \left(\frac{180mcd}{20mA}\right) 1.3636mA = 12.27mcd$$

Example 2: Design a circuit to drive 500mA through a 3W white LED.

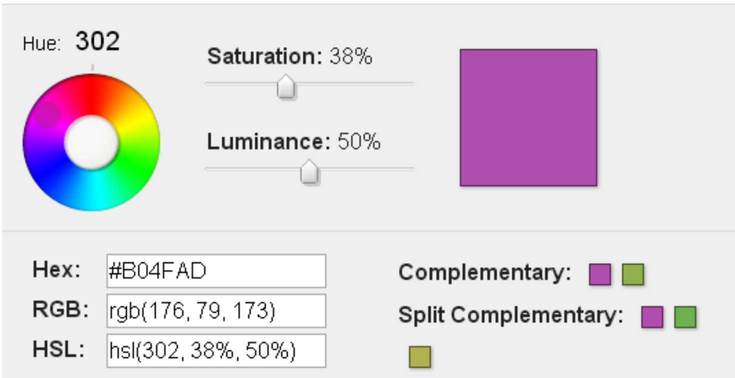
Solution: Assuming a 12V source, the resistance needed is

$$R = \left(\frac{12V - 3.4V}{500mA}\right) = 17.2\Omega$$



Example 3: Using an RGB LED, you can output any color. For example, purple consists of

- 176/255 (69%) red
- 79/255 (31%) green
- 173/255 (68%) blue



https://www.rapidtables.com/web/color/color-wheel.html

Design a circuit using the Piranha RGB LED to output

- 6900 mcd red
- 3100 mcd green
- 6800 mcd blue

Solution: Assume a 10V power supply. The current and voltages you need are:

Red: 6900 mcd

$$I_r = \left(\frac{6{,}900mcd}{10{,}000mcd}\right)20mA = 13.8mA$$

$$R_r = \left(\frac{10V - 1.8V}{13.8mA}\right) = 594\Omega$$

Green: 3100 mcd

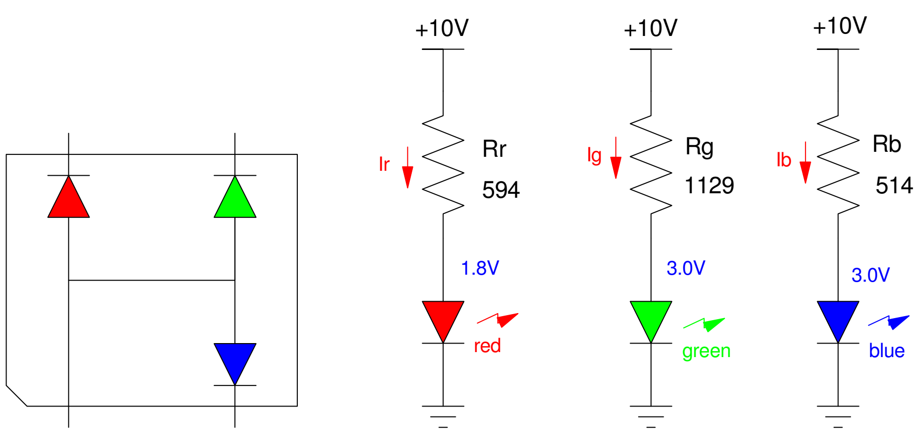
$$I_g = \left(\frac{3{,}100mcd}{10{,}000mcd}\right)20mA = 6.2mA$$

$$R_g = \left(\frac{10V - 3.0V}{6.2mA}\right) = 1129\Omega$$

Blue: 6800mcd

$$I_b = \left(\frac{6{,}800mcd}{10{,}000mcd}\right)20mA = 13.6mA$$

$$R_b = \left(\frac{10V - 3.0V}{13.6mA}\right) = 514\Omega$$



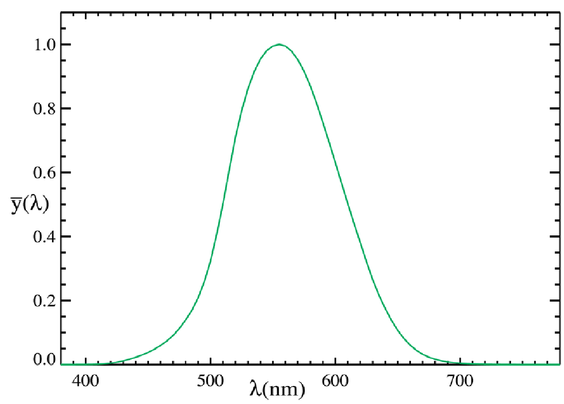
Creating purple with a Piranha RGB LED

Sidelight: What's the efficiency of LED light bulbs?

(data from http://www.1000bulbs.com and Wikipedia.com)

That sort of depends upon how you define 100% efficient.

- The human eye is most sensitive to green light. If you limit yourself to green light, 100% efficiency is 683 lm/W.
- If you want white light, that depends upon how much energy goes into each color. Blue and red light is less efficient since the eye is less sensitive to these colors. A standard definition of 'white' is a black body radiating at 5800K - with its light clipped to the region (400nm - 700nm). With this definition, 100% efficient is 251 lm/W. All of the energy is going into visible light, so it's a reasonable definition of 'efficient'.



Sensitivity of the human eye to light: (www.wikipedia.com)

Assuming white light bulbs, you can determine their efficiency with the latter definition by computing their lumens per watt and dividing by 251lm/W

	W, Lumens	Price		lm / W	eff
		new	@ 1000 hr		
Incandescent (c. 2000)	60W, 300 Lm	-	-	5.27	2.1%
Incancescent: GE 66247 (3)	43W, 620 Lm	$1.36	$1.38	14.4	5.7%
Halogen: Phillips 60W (3)	43W, 750 Lm	$1.46	$1.48	17.4	6.9%
CFL: Philips 823031 CFL (3)	13W, 860Lm	$3.50	$0.36	66.2	26.4%
LED: Sylvania 74765 (3)	8.5W, 800 Lm	$0.83	$0.075	94.1	37.5%
Street Lights:					
Mercury: GE 175W Street (3)	175W / 7850 Lm	$11.29		36	14%
Sodium: BulBrite (3)	70W / 6000 Lm	$8.95		86	34%
100W LED (4)	100W / 9000 Lm	$8.29		90	36%
LED Light (theory)				201	80%
Ideal Black Body	-	-		251	100%

(3): www.Amazon.com (4) www.ebay.com

Incandescent light bulbs date back to 1802 with Edison improving on the design in 1878. The first street lights used incandescent lights in 1879 in Newcastle on Tyne. A typical incandescent light bulb is about 2% efficient - meaning they're 98% at producing heat, 2% efficient at producing light. The Barbie Easy Bake oven used a 25W light bulb in a metal box to bake brownies, cupcakes, etc. (Wikipedia)

Halogen light bulbs date back to 1882 and are slightly more efficient than incandescent light bulbs. Halogen bulbs ionize a gas (typically Xenon or Iodine) to produce light. These were banned in Europe in 2016 and in Australia in 2020 due to their inefficiency. (Wikipedia).

The mercury vapor light was invented in 1892 by Leo Arons and are much improved lights in terms of efficiency. These lights use mercury (of course) and were banned in Europe in 2015. Ballasts for mercury vapor lights were banned in the U.S. in 2008 (Wikipedia).

Low pressure sodium lights started replacing halogen and mercury vapor lights after WWII. One major problem with sodium vapor lights is they have strong emissions in the Hydrogen II region of the spectrum - the same wavelength that nebulas emit in outer space. Likewise they are strongly disliked by astronomers.

LED street lights started to be used in 2014 and are presently the light of choice for cities. They are more efficient than other lights and they are directional to boot: the light can be directed down to the pavement rather than everywhere.

One of the main reasons that incandescent and halogen lighting has been banned (in Europe at least) deals with energy conservation, global warming, and reliability of the power grid.

Back in 1990, about 20% of the energy produced in the United States went to lighting[1]. By switching to more efficient forms of lighting (LED vs. incandescent), this has been reduced to about 5% of the total electricity energy used in 2019[2]. This reduction means

- Less coal needs to be burned and less CO2 is put into the atmosphere,
- Fewer power plants need to be built,
- Older, less efficient power plants can be retired, and
- Brown outs and blackouts are avoided - situations where energy demand exceeds supply.

This is why the less efficient lights were banned in Europe. You can still buy them in the U.S.

1 www.lighting.sandia.gov

2 https://www.eia.gov/tools/faqs/faq.php?id=99&t=3